Blobtacular: Surfacing particle systems in "Pirates Of The Caribbean 3"

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Figure 1: Left: Blobtacular is used to generate water dripping off a pirate ship. Right: A large teapot is sprayed with blended micro-teapots.

We have developed a tool for efficient and flexible surfacing of particle systems using various optimized level set techniques and data structures. Smoothed Particle Hydrodynamics (SPH) is a popular technique in production environments since it allows for relatively fast simulations of fluid effects like splashes, filaments, and thin-sheets. These elements are computationally intensive to produce with grid based fluid solvers. The traditional approach to surfacing particle systems uses CSG blending of spherical metaballs sampled on a dense, regular 3D grid. This severely limits the quality of the resulting surfaces due to resolution and computational overheads in both time and memory. Consequently SPH surfaces often have a characteristic "blobby look" that clearly reveals the underlying particles. Furthermore, particle systems are typically sparse and occupy large (empty) spaces, making them very inefficient to sample on dense, regular 3D grids. This sketch outlines different techniques that we developed to overcome these shortcomings in actual productions.

Reduced computational overhead: We employ efficient data structures and algorithms to achieve high surface resolutions and low execution times. The algorithm starts by partitioning the particles into sub-blocks, each associated with simple but fast linear particle arrays and compact bit masks. Each array is then sequentially accessed to composite the particles into the respective sub-volume using appropriate estimates of the particle stencils derived from anti-alising techniques described below. This avoids typical nearest neighbor searches in slow tree data structures (*e.g.* KD-Trees), instead performing fast, random-access into the dense sub-volume. After each linear array is processed we have two options: 1) Use the bit-mask of the corresponding sub-volume to perform fast direct mesh extraction. 2) If the post-processing described below is desired, we lexicographically push the sub-volume into a compact narrow band level set data structure[Nielsen and Museth 2006] (DT-Grid). Since only a single dense sub-volume is allocated at any time, the overall memory bottleneck is effectively 1) the mesh or 2) the DT-Grid. This implies that our approach is capable of representing implicit particle surfaces of effective resolutions exceeding 5000^3. Note that algorithm 1) achieves interactive performance with effective resolutions up to 400^3 and several thousand particles. At 1000^3 and close to a million particles both algorithms produce frame-rates in the order of a few minutes. In contrast this takes several hours using existing methods in Houdini.

Temporal anti-aliasing: We utilize the velocity of the particles to improve the temporal coherence of resulting surface. Each particle kernel is extended backward in time, imitating the hyperbolic information flow characteristic of fluid advection. This is achieved by means of the particle velocities computed during the SPH simulation. We can further augment this process with noise functions and scaling to obtain various artistic effects.

Spatial anti-aliasing: To reduce artifacts from sparsely sampled regions of space we can blur the implicit particle kernels corresponding to anisotropic diffusion of meta-balls (*e.g.* ellipsoids vs spheres). For this we have developed a new technique based on diffusion-tensor analysis of the particle densities[Zhukov et al. 2003].

Animated geometric texturing: To enhance artistic expression we can use arbitrary geometry for the particle footprints by means of local level sets for the kernels. We can even perform complex animations of this geometry to simulate breakup and fracturing.

Flexible post processing: For added flexibility we can use a large toolbox of existing techniques. This includes morphological operations to remove holes or disconnected pieces, and surface smoothing by means of mean-curvature based level set flow, as in [Museth et al. 2002]. Polygons can be extracted very quickly due to the use of bit-masks or narrow bands, and the resulting mesh can be filtered by any number of mesh editing tools.

Different combinations of these techniques allowed us to create dramatic fluid splashing effects in "Pirates of the Caribbean: At World's End" that would otherwise have been unfeasible.

References

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